LIGHT

ITS USE AND MISUSE

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A PRIMER OF ILLUMINATION PREPARED
UNDER THE DIRECTION OF THE
ILLUMINATING ENGINEER-
ING SOCIETY

ILLUMINATING ENGINEERING SOCIETY

THE ILLUMINATING ENGINEERING SOCIETY was organized in 1906 to advance the theory and practise of illuminating engineering and to disseminate knowledge relating thereto. The Society now has about 1600 members who are interested in the subject of lighting from various standpoints: engineering, economic, hygienic, esthetic.

The Society has no affiliation with any commercial organization. Any one interested in its objects may become a member.

LIGHT: ITS USE AND MISUSE

It is the purpose of this publication to assist the user in making artificial light effective, whether the light be produced by oil, gas, electricity or otherwise.

By proper use you can get good illumination from any of these sources, but by misuse you are likely to get lighting that is bad, costly, and even dangerous to the eyesight.

ILLUMINATION AND COMFORTABLE VISION

To see easily and comfortably you must select the lamps, fixtures and globes and arrange the lights so as to best suit the particular conditions which have to be met, but certain principles which must always be followed may safely be laid down.[1]

Fig. 1.—Pupil of eye expanded to let in plenty of light when illumination is dim.

Same pupil contracted to shut out excessive light.

Don't Judge Illumination by the Brightness of the Lamps

Judge the light you are getting by the way it helps you to see. Do not think because a lamp looks glaring and brilliant that it is giving you good light. It may be merely giving you too much light in the wrong place. On the other hand, a well shaded table lamp may look dim because it is well shaded, and still be giving first-class light for working purposes.

[1] To understand these principles better, take a glance at the eye and see how it works. Figure 2 shows the parts of the eye as they would appear if it were cut through from back to front vertically.

You must get enough light to see by, and as you see things chiefly by the light which they reflect, it is evident that dark colored objects which reflect light badly require more light than do light colored objects to see them comfortably. That which is quite sufficient for sewing on white cloth, for example, will not do at all for working on black cloth.

Don't Work in a Flickering Light

See that your light is steady. If you leave a dark room and go into bright sunshine the sensation is unpleasant to the eye;

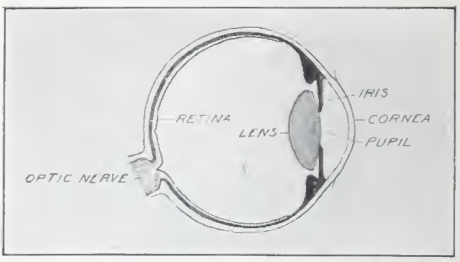

Fig. 2.—The eye: essential parts shown in section.*

if you use a light that flickers, you get this same unpleasant sensation, perhaps as rapidly as twenty times a minute. Furthermore, the eye endeavors to adjust itself to suit the light;

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*In the process of seeing, the light passes through the cornea, pupil, and lens of the eye to the retina, just as in a camera light passes through the lens to the sensitized film. The picture is formed on the retina, which is a layer made up of the ends of nerve fibers which gather into the optic nerve and go directly to the brain. The optic nerve sends along the picture to the brain for notice. The lens of the eye, unlike that of the camera, automatically changes in thickness, to focus or make a clear image on the retina for seeing at different distances. This focusing action is called the accommodation of the eye, and when the light is dim or bad the focusing muscle vainly hunts for some focus which may make objects look clear and gets tired in trying to do it. The muscles which move the eye about also get tired in the same way and the result is eye-strain, which stirs up pain and headache just as any other over-tired muscles of the body may set up an ache.

The iris (which gives the eye its color) serves to regulate the amount of light which reaches the eye. In very dim light it opens out, making the pupil big, as shown in figure 1, and in very bright light it shuts up as shown, and thus keeps out a flood of brilliant light which might hurt the retina. The protective action of the pupil is pretty good, but by no means complete, for it seldom gets smaller than shown in the illustration, however bright the light.

if the light flickers it keeps the iris of the eye "see-sawing," as it were, and the muscle that governs it gets tired and reacts on the nerves to cause discomfort and pain. Reading in railway trains causes similar strain; the eye muscles get tired in trying to follow the shaking page, and are likely to provoke a headache.

Don't Expose the Eyes to an Unshaded Light

It is bad to have an unshaded brilliant light glaring into the eyes, for it throws hard labor upon them in an effort at adjust-

Fig. 3.—Very bad lighting. This man receives, full in the face, both direct light from the unshaded lamp and reflected glare from the table top and papers.

ment. This applies even to common electric, gas, or oil lamps. (See figs. 3 and 4.) While artificial light may be made a good substitute for daylight, you have constantly to beware lest rays that are too bright, either from the lamps or from their reflections, hurt the eyes. You can get reflections, so bright as to be harmful, from polished metal or glass, from bright varnished surfaces, or even from glossy white paper upon which the light falls.

A bright light fairly in the field of view means a very brilliant light on the retina, producing fatigue. Everyone knows the blinding sensation of looking at the sun with its sequence of dazzling colored images. Babies are here common sufferers when careless mothers or nurses allow them to lie in their carriages with eyes exposed to the unclouded sun. Bright artificial lights, in a less degree, do the same thing to all of us.

Fig. 4.—Faulty arrangement of dining-room lighting. The lamps exposed in the dome shine in the eyes. Trouble is aggravated by general darkness of the room.

And when you get a bright light in the field of view, the pupil tries to shut it out; in so doing it renders less bright things all but invisible. Thus it is hard to see things which are nearly in line with a brilliant light, as you often find in facing an automobile headlight, or looking into a show window like fig. 5.

Place an unshaded lamp in front of a picture on the wall and then stand back a few feet and note how much of the picture

you can see clearly. Then hold a book or paper at arm's length so as just to cover the bright light and note the way in which the picture clears up. Again, put an unshaded lamp about a foot in front of your eyes and try to read a newspaper just beyond it. Then shade your eyes from the lamp and try it again. You will soon find out in this way that lamps can be so placed that they will be a hindrance rather than a help in seeing. (Compare fig. 6 with fig. 5.)

A Couple of Simple Experiments

From time immemorial mankind has received its light mostly from the sky. Consequently the part of the retina on which the light from above chiefly falls is pretty well used to it, while bright light from below, falling on the part of the retina which commonly gets light only from grass or dark pavements, may be very irritating and unpleasant. Thus the glare from snow and sand is not only disagreeable on account of its intensity but because of the unusual direction from which it comes. Just so with a brilliant beam reflected from glossy paper on which you are writing. Its rays strike you from an unusual direction and are harmful for that reason. Other smooth and shiny surfaces deliver an equally hurtful assault on that sensitive and much abused organ,—the eye.

Best Direction of Light

Don't Read Facing the Light

It is best to have the light come from above and somewhat sidewise, as it commonly does in nature, so that you will not get a brilliant reflection or glare from what you are trying to see. In reading and writing it is better to have the light come from the left, to avoid getting a shadow of the hand that holds the book or pen. Let the lamp be just far enough behind to keep direct reflections from the paper out of the eyes. (See figs. 7, 8, 15, 16.) But what has been said of reflections from paper applies with even more force to the case of polished metals, or the like, over which one is busy. Individual lights placed close over the work are very likely to produce these troublesome direct reflections and consequently such lights are falling into disuse. In an interior otherwise dark, their use is open to the further objection of giving bright spots of light and so producing too violent contrasts of light and shade. (See figs. 17, 18.)

Fig. 5.—Poor arrangement for display. You see the lamps instead of the sweets.

Fig. 6.—Excellent arrangement for display. No lamps in sight. Every garment is brightly lighted.

Don't Use a Bright Light Against a Dark Background

Almost any light will glare unpleasantly if the surroundings are thoroughly dark. As an extreme illustration, the light from a big arc lamp hung close to the sidewalk may be very annoying at night, but by day you would hardly notice it. Just so a bright lamp against a dark background may be annoying, while against a light background it would not be so unpleasant.

LAMPS, FIXTURES, GLOBES, REFLECTORS

One may choose to-day among lights of many kinds. There are at hand candles, oil lamps, open flame gas jets, upright and inverted mantle gas lamps, electric incandescent lamps of carbon and of tungsten, electric arcs of half a dozen varieties, besides mercury-vapor tubes, acetylene lamps, and so on through a long list.

What do you wish to use a light for? To read or write by, to bring into view the working parts of a machine, to match colors, to display goods or pictures; or merely to make a pathway safe and plain? Each case is to be studied by itself, and the effect is to be accomplished by such lamps, globes and reflectors as, properly disposed, will insure ample lighting without glare, and yet with strict economy.

However good and suitable the lamp, it will be put at a disadvantage unless the lighting fixture which carries it is designed to hold the lamp in the right position to enable one to best utilize the light which comes from it. Prettiness in a fixture is well enough; but let the fixture be serviceable first; then it may be also as pretty as you please. But don't buy prettiness if it makes war on good service.

Daylight is naturally well diffused; but artificial light, poured out as it is from mere points, or narrow surfaces, needs to be tempered or softened by shades. And it sometimes further requires to be directed upon a desk or table or other object. In some cases it is better to adopt indirect methods, and throw the beams of a lamp upon a ceiling whence the rays are scattered. For every particular need there is ample provision amid the abounding lamps, globes and reflectors of present day designers.

Arranging Lights

Two methods are usual in arranging lamps: first, to secure general illumination by so placing the lamps that you may see with comfort anywhere in a room; second, in cases where a bright light is not necessary throughout a room, local illumination can be planned, placing the lights where they will be most used, always remembering that it will not do to localize light too much, since you need

Fig. 7.—A bad position for reading. In spite of the shaded lamp, glare from paper reflected into eyes is very trying and harmful.

for comfortable seeing a fair quantity of light broadly distributed.

PRECAUTIONS TO BE TAKEN IN PLACING AND SHADING LIGHTS

In any artificial lighting the lamps should be so well shaded that the eye does not see them directly nor brilliant reflections from them. You can accomplish this end by putting the light

in diffusing globes of, for instance, ground glass or white or opal glass or other translucent material. To secure the best diffusion, the globes should be dense enough not to reveal the form of the actual light source within, but to give the effect of the light pouring forth from the globe as a whole. (See fig. 9.)

Diffusing and Shading by Globes and Reflectors

Another way of accomplishing the same result is to put an

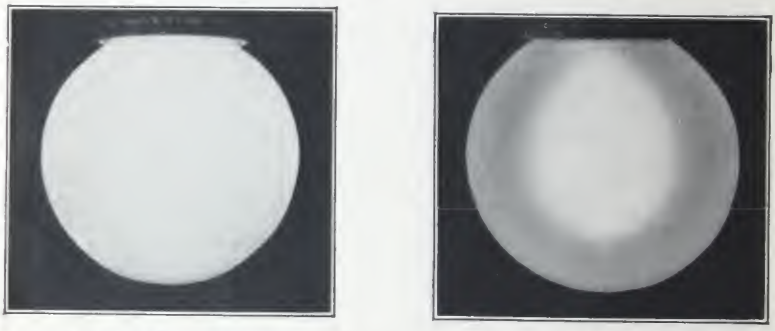
Fig. 8.—Good position in reading. No light directly hits the eyes and no glare is reflected from the book.

open shade on the lamp, which screens it and reflects downward much of the light which would otherwise idly fall on the walls or ceiling. (See fig. 10.) Such shades may be of mirrors or polished metal or white or opal glass, or of prismatic glass,—all of which, in a measure, work alike. Glass shades are generally preferable to metal ones, for some light penetrates them sidewise,—enough to keep the upper part of the room from being too dark. When a larger proportion of light is required below the lamps than is shown in figure 10, an opaque

shade as shown in figure 18 may often be advantageously used. The general method of lighting is much the same in both cases.

Indirect Lighting

Another scheme successfully used to shield the light is to turn the light from the lamp upward on to the ceiling by means of an opaque reflector underneath. The reflector conceals the lamp, and the brightly illuminated ceiling by which the light is diffused serves as the actual source of the illumination. (See fig. 11.) This plan should be used only on white or very light ceilings and is subject to a heavier loss for securing diffusion than some other methods, but often this loss is reimbursed by the thoroughness with



Opal glass globe. Ground glass globe.

Fig. 9.—Within each globe is a lamp of the same candle-power. Note the superior diffusion of the light by the opal globe.

which the ceiling diffuses the rays that fall upon it.

Semi-indirect Lighting

A method frequently used for combining some of the advantages of both direct and indirect lighting is to place the lamps in a bowl of diffusing glass. This bowl reflects upward part of the light as in indirect lighting and lets through part as in direct lighting. (See fig. 12.)

Don't Use Local Lighting by Itself

General Illumination Usually Best

In ordinary cases general illumination is the best way of lighting an interior unless some of the work in hand, as sewing dark goods or reading very fine print, demands exceptionally strong lighting in some parts of the room. In this case local lights may be added,

but they ought not to be used without pretty strong general illumination. The commonest sort of localized lighting is that furnished by a table lamp. Such a lamp should always be shaded to keep the direct light out of the eyes,—best by a translucent shade which will add something to the general illumination.

In any one of these plans for general illumination, lights should be so placed as to give at least fairly uniform lighting

Fig. 10.—General illumination by direct lighting; lamps shaded by diffusing glass reflectors.

everywhere in a room, otherwise there may be strong and jarring contrasts of light and darkness.

In using shades open at the bottom, such as are very common, their shape and character can be so chosen as to distribute the light precisely as desired; this result can in less degree be accomplished by using enclosed globes or by indirect lighting.

Any of the schemes here sketched can be made to give good results. The choice between them turns upon just what task is required of the light and what its surroundings are to be.

Ordinarily, lighting from shades open at the bottom gives a stronger light than other methods, but you must carefully avoid glare in these cases. Lighting by wholly indirect means, in which all the rays are diffused from the ceiling, demands lamps of extra power for the same illumination, but requires little care to avoid glare. Rooms lighted from diffusing globes or bowls take an intermediate position with respect to freedom from glare.

Fig. 11.—General illumination by indirect lighting; lamps are concealed in opaque reflectors and the light is diffused from the ceiling.

Misplaced Brackets

For a lamp to do its best work, it should not be too near a wall, especially if this wall is dark. Hence only very small rooms can be well lighted by the usual side brackets, say 4 to 6 feet high. In a large room the eye cannot avoid glare from such brackets unless their lamps are so heavily shaded as to dim the room. In large rooms where brackets can be placed high enough to be out of the general view, they may be used to advantage; and they are often convenient for occasional use, as in bed rooms, when the room is also lighted by other means.

ECONOMY AND EFFICIENCY

Don't Waste Light by Using the Wrong Reflectors

By using reflectors you can put the light from a lamp where it will do the most good, much as an automobile headlight sends the light along the road just where it is wanted. In fig. 3 there is a lamp without any shade or reflector and you will see that the light goes in all directions, only a

Fig. 12.—General illumination by semi-indirect lighting; lamp is concealed in diffusing bowl.

small part of it falling on the level of the table where it is needed. The rest hits the walls and is reflected about the room, losing intensity at each reflection. Obviously an unshaded lamp does not throw the light where it is wanted. To ensure the light falling upon the table you must use a reflector that will bring it there.

Of such reflectors there are three general types, either of glass or of metal, which we may call concentrating, semi-concentrating, and distributing. (See fig. 13, (a), (b) and (c).) The first acts almost like an automobile headlight, throwing

(a) Concentrating reflector: lights a small area brilliantly.

(b) Semi-concentrating reflector: lights a larger area less brilliantly.

(c) Distributing reflector: lights a wide area moderately.

Fig. 13.—Reflectors put the light where you want it; (a), (b), and (c) have lamps of the same candle-power. (These pictures are intended only to show, in a general way, the effect of different types of reflectors.)

its light downward into a comparatively small area. The second kind spreads out the light over a much wider area, of diameter perhaps as great as the height of the lamp above the table, while the third is planned to light a comparatively big area not very intensely at any one spot.

No reflector ever increases the total light that streams out of a lamp; it only puts the light where it is needed instead of letting it go unguided.

Fig. 14.—Each of these two little rooms receives the same light. Dark walls absorb most of the rays of light in left-hand room.

Height of Lamps

With proper reflectors, their height above the table, counter or bench ordinarily makes little difference since it is the purpose of the reflectors to send the light where it will do the most good.

Effect of Dark Walls and Colored Globes

Because dark walls absorb light strongly instead of reflecting it they demand much stronger lamps for sufficient illumination than do light walls. (See **fig. 14.**) A very dark wall-paper or a dark wood finish may require three or four times as much light as a really light finish. Dark reds, greens, and browns reflect only 10 to 15 per cent. of the light which falls on them. White, cream color, and light yellowish tints may reflect over one-half the light.

Likewise, deeply tinted globes and shades absorb much light —a fact which must be borne in mind in considering economy.

Don't Use Shallow Reflectors

All reflectors should come far enough down over their lamps to prevent you from seeing the bright sources of light themselves without actually looking upward.

Don't Let Lamps and Globes Get Dirty

Dirt on lamp chimneys, electric bulbs, globes, or reflectors

Fig. 15.—Don't place a desk lamp like this; it glares from the paper and shines in your eyes besides.

absorbs and wastes much light. The country over, it is safe to say that millions of dollars are wasted every year by letting lamps become foul and dust laden. Nor is there any economy in using electric bulbs until they blacken. It pays to renew promptly blackened bulbs and defective gas mantles.

Don't Save Light at the Expense of Your Eyes

Saving light at the cost of eyesight is false economy. To get good lighting it is generally necessary to diffuse the light

from the lamps either directly, by opal or ground glass shades, or indirectly by turning the light first on the ceiling or wall. The use of ground glass involves the absorption of 15 to 20 per cent. of the light to secure diffusion, opal glass of various kinds from 20 to 40 per cent., while some forms of art glass and most diffusing ceilings absorb more than half the light that falls upon them. Even though all these appliances absorb light in the process of diffusion, there is gain in their use because they yield rays more grateful to the eyes.

Real and False Economy

Fig. 16.—If you must use a desk lamp, put it at the side of the desk in this position. If an open reflector is used let it be of the diffusing type. Better still is a reflector with a diffusing glass bottom.

But your eyes may tire easily even with good lighting. If so, consult an oculist and don glasses if you need them. Eye-strain often comes from defective eyes as well as from faulty lights.

Economy in Selecting Lamps

In gas lighting, except in rare cases, mantle burners are much more economical than open flame burners. Similarly, in electric lighting, tungsten lamps are usually more economical than carbon

filament lamps. The carbon lamps cost less to install or replace, but much more for electric current.[2]

AMOUNT OF ILLUMINATION REQUIRED

The common unit of illumination is the foot-candle, meaning thereby the light which the object would receive from a

Fig. 17.—More light in the eyes than on the work and not enough light in the room. Sharp shadows and much glare from the polished metal. Discomfort to the worker: loss to his employer.

standard candle at the distance of one foot. This is the measuring rod, as it were, by which comparisons are made.

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[2] The amount of electricity taken by an electric lamp is expressed in watts. Most electric lamps now manufactured have the number of watts which they are rated to consume printed on a label on the bulb. The old-fashioned carbon filament incandescent lamp of 16 candle-power has the candle-power on the label, and takes from 50 to 60 watts.

How to Figure Cost of Light

No absolute rule can be laid down for the number of foot-candles required for good seeing. Individuals differ widely in their requirements; and the conditions under which the light is used cause still greater variations in requirement. However, where lighting arrangements are well planned it has been

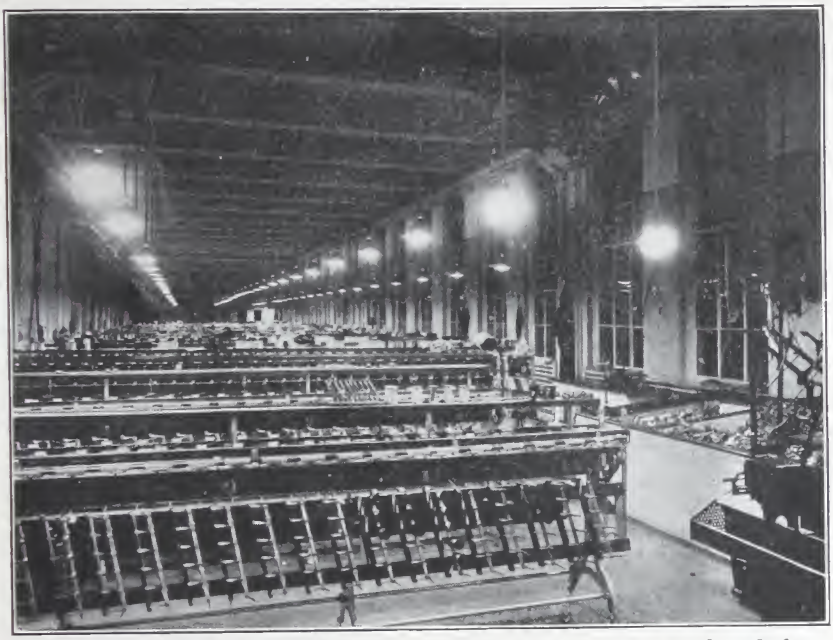

Fig. 18.—Example of good general illumination in a factory; the whole area is uniformly and brightly lighted.

found by experience that ordinary reading, writing, or work on white or light colored material, can comfortably be carried on

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To determine the cost of operating an electric lamp, divide the number of watts it consumes by 1000 to reduce it to kilowatts, and multiply the number of hours the lamp is to be operated by the kilowatts to obtain the kilowatt-hours of electrical energy. The kilowatt-hours multiplied by the rate per kilowatt-hour which is charged gives the cost of operation for the stated time.

The consumption of gas lamps is expressed in cubic feet of gas per hour. The number of cubic feet of gas per hour taken by a burner, divided by 1000, and multiplied by the cost per thousand cubic feet of gas, and by the hours of burning, gives its cost of operation for the stated time.

The consumption of open flame burners is commonly taken at 5 cubic feet per hour. Upright single mantle burners usually take from 3½ to 5 cubic feet per hour, though some smaller ones take less. Most individual inverted gas mantle burners take from 3 to 3½ cubic feet per hour.

by most people with an illumination of 2 to 3 foot-candles. For sewing dark goods, or reading fine type, 5 foot-candles are none too much, while for drafting, engraving, watchmaking, working on black cloth, and the like, from 7 to 10 foot-candles should be furnished.

Artistic Effects

In a room suitably arranged for comfortable seeing, you may have plenty of light, but the general effect may be displeasing. The illumination may quite fail to bring out the good points of the room in architecture and decoration, or may play pranks with the appearance of

Bust lighted from above and in front.

The same bust lighted from directly overhead.

Fig. 19.—Bad lighting defeats good art.

persons or things in the room. (See fig. 19.) One may not object to ghastly tints in a factory, but in lighting a drawing room such effects would not be tolerated. Hence one often should sacrifice strict economy to get the most pleasing effect in the room. The fixtures that carry the lights should harmonize with their surroundings if the general effect is to be

agreeable. Handsome fixtures have a decided decorative value whether their lamps are lighted or not. As strongly colored objects give something of their own hue to all the light which they reflect, the color of lamp shades, walls, and furnishings plays an important part in the artistic effect.